V, No. 1 JANUARY, 1944

Technology
Technology
Communication
kelp
JAN 2 6 1944

BORDEN'S REVIEW *of* NUTRITION RESEARCH

TRACE ELEMENTS IN NUTRITION
II. MANGANESE

BORDEN'S REVIEW
of
NUTRITION RESEARCH

Reviews and summaries of research information concerning nutrition and foods. Published monthly, except during July and August, by THE BORDEN COMPANY, 350 Madison Avenue, New York 17, N. Y. Edited by Ruth Woods.

THIS issue of *Borden's Review of Nutrition Research* appears in a new format designed primarily to comply with the Government's conservation program. The new design also provides improved legibility and a more compact form without curtailment of editorial content.

TRACE ELEMENTS IN NUTRITION
II. MANGANESE

At the present time, at least thirteen mineral elements are recognized as being essential for animal life. They are calcium, phosphorus, magnesium, sodium, potassium, chlorine, sulfur, iron, copper, manganese, zinc, iodine* and cobalt. Of these, the last five have been shown to function in such minute quantities that they have been termed "trace" elements in nutrition. Although these mineral elements are vitally important in metabolic processes, more than trace quantities of some of them may be toxic.

In addition to these thirteen elements, traces of other minerals have been found to be normal constituents of various animal tissues and fluids. These include arsenic, aluminum, rubidium, bromine, fluorine, silicon, barium and nickel. Some of the elements in this group, notably fluorine† and bromine, are known to be of significance in human physiology. More specific information concerning the biological activity of the others may be revealed by future research.

Discovery of Manganese as a Nutritional Trace Element

In 1897, Bertrand (1) formulated the theory that manganese is the active constituent of certain enzymes, the oxidases. Although this theory was later disproved, interest in the biological role of manganese has dated from that time. The earliest investigations were concerned primarily with the occurrence and distribution of this element in living tissue. It was found in the blood and organs of man and of all the experimental animals which were studied (2). Plant tissues were found to contain much more manganese than animal tissues. An extensive review of the earlier literature regarding the biological occurrence of manganese was published in 1920 by Reiman and Minot (3), who reported the greatest storage in the liver, pancreas, lymph nodes and kidneys. This was followed two years later by a review of the role of manganese in plants by McHargue (4).

> Manganese is now known to be essential for all plants. Without it, simple plants fail to grow, while more complex ones become etiolated. Manganese is now used routinely as an ingredient of plant nutrient solutions, in soil fertilizers, and in culture media for many species of fungi and bacteria.

Similar studies were conducted by other workers during the course of the next ten years. Skinner *et al* (5), in a study of the manganese metabolism of the rat, found that this element is stored throughout

---

* See *Borden's Review of Nutrition Research*, September 1943.
† See *Borden's Review of Nutrition Research*, December 1943.

life, the principal depots being the liver, muscles, bones and skin. They demonstrated, further, that extra supplies of manganese in the diet markedly increased the rate of storage of this substance.

Early Studies on Manganese Metabolism:

A number of experiments with laboratory animals was carried out by various investigators during the latter half of the 1920's in an attempt to demonstrate the importance of manganese in normal animal metabolism. The general implication of these experiments was that manganese is a significant factor in animal nutrition and that small supplements to ordinary adequate diets usually resulted in beneficial effects on the animals. Thus, for example, it was reported (6) that the addition of manganese, in amounts equivalent to one part in from 2000 to 10,000 parts of ration, improved the appearance of rats, increased their activity and stimulated more rapid growth in the offspring. Following this, a group of French investigators (7) reported similar results with dogs fed small supplements of manganese not oftener than once every three days. Still other workers confirmed the beneficial effects of small amounts of manganese in synthetic diets (8, 9, 10), although it was found that the administration of manganese in too large quantities retarded, rather than stimulated, growth (10).

From these early experiments, it was apparent that manganese, in minute, optimum quantities, exerts a beneficial effect upon the animal organism. It was not until 1931, however, that conclusive evidence of the essentiality of manganese in the diet was obtained. At that time, Orent and McCollum (11), through the use of more highly purified diets, found that male rats which had been reared from weaning on a diet adequate except for manganese, became sterile and exhibited degeneration of the reproductive organs after ninety days. Females on the same diet produced young which failed to live, and, in addition, refused to suckle either their own young or normal young from the stock colony. No deleterious effects were noted upon growth, hemoglobin regeneration or the regularity of the estrous cycle. At about the same time, Kemmerer, Elvehjem and Hart (12), conducting similar studies with mice, found that manganese deficiency did retard growth and resulted in defective ovulation. These latter observations were confirmed by Skinner *et al* (13, 14) who reported that manganese aided in earlier attainment of sexual maturity and that, when administered with sucrose, it restored normal estrous cycles. A few years later, Keil *et al* (15) demonstrated that rats on

similar manganese-low diets would not reproduce in a second generation unless manganese was supplied.

In 1935, Daniels and Everson (16) fed a manganese deficient diet to rats and confirmed the earlier observation of Orent and McCollum that females on such a diet produce non-viable young. They found, however, no interference with lactation and attributed the cause of mortality in the young to imperfect fetal development resulting from manganese deficiency in the maternal diet and not to failure of lactation. More recently, Shils and McCollum (17) have indicated that manganese is essential for growth, as well as for proper reproductive functioning. In accordance with the findings of Daniels and Everson, they report also that manganese-deficient females, while losing their own young, are able to suckle normal foster young. The few young, born of deficient mothers, who managed to survive to weaning, uniformly showed weakness and lack of muscular coordination (most pronounced during the third week of life), with poor maintenance of balance and retarded growth persisting throughout life.

McCollum *et al* (17) attribute the differences in results between their earlier investigations (11) and those of Daniels and Everson (16) to possible differences in the actual manganese content of the various diets used. It is difficult, even at the present time, to prepare purified diets as completely free of manganese as desired. McCollum and Shils suggest, therefore, that different deficiency symptoms occur at different levels of manganese intake. They suggest, further, that unknown dietary relationships may also be responsible for differences in experimental results. In this connection, it is interesting to note that at least one such dietary relationship has already been indicated by Perla and Sandberg (18, 19, 20) who have demonstrated an apparent interdependence between manganese and thiamin.

Interdependence of Manganese and Thiamin: The discovery of an apparent relation between manganese and thiamin in metabolism came about through a series of experiments on the effects of thiamin supplementation. It was found (18) that rats on a standard, adequate diet supplemented with 400 micrograms of vitamin B_1 daily, (about 30 to 40 times the minimal requirement for the rat) exhibited marked interference with lactation, loss of maternal instinct, cannibalism, and progressive loss of fertility. These symptoms were pronounced in the parent generation, but even more so in the filial generations. In one of the filial generations, for example, it was found that more than 90 per cent of the young were neglected and eaten.

All of the symptoms disappeared when the thiamin supplement was reduced to about 40 micrograms per day.

The appearance of these symptoms was extremely surprising. This was especially so in view of the statement by Williams and Spies (21) that as much as 160 to 1000 micrograms of thiamin could be given daily to rats on a standard Sherman diet without any signs of toxicity. Perla and Sandberg concluded, therefore, that an "interference with some other factor in the diet might have induced the manifestations observed."

Inasmuch as the administration of thiamin supplements gave rise to symptoms strikingly similar to the symptoms of manganese deficiency described by Orent and McCollum (11), Perla and Sandberg believed that manganese might be involved. Accordingly, manganese was added to the diets containing excess thiamin, with the result that all of the animals were restored to normal. Two milligrams of manganese per animal per day was sufficient to neutralize the toxic effects of an excess of 400 micrograms of thiamin. No toxic disturbances were noted when excesses of manganese and thiamin were given simultaneously.

From this work it was concluded that a balance must exist between thiamin and manganese, the suggestion being made that manganese acts as an essential catalyst in the oxidative processes in which the vitamin is involved. Perla and Sandberg state:

> "Manganese is essential in the utilization of vitamin B_1 in the tissues and is intimately bound up in the role of vitamin B_1 in the physiology of the organism. It is also suggested that variations in certain constituents of the diet, such as manganese, may greatly affect the vitamin B_1 requirement. With the use of large amounts of vitamin B_1 in therapy, an adequate supply of manganese must also be made available."

As a result of the work of Orent and McCollum, and of subsequent investigators, manganese emerged from its obscure role as a possible nutritional factor, and became recognized as a specific nutritional requirement for normal growth and reproductive function in the animals studied.

Manganese in Poultry Nutrition:

Interest in the nutritional significance of manganese has been revived recently by the demonstration of its association with certain poultry disorders. The manganese requirements of fowl, particularly of the chicken, are much higher than those of any mammal studied. For this reason, deficiency symptoms in the chick are more readily apparent and of a more severe nature than those in other animals.

One of the most important manifestations of manganese deficiency in the chick is the development of the condition known as perosis or "slipped tendon." This disease was first described in the literature about fifteen years ago and since then has stimulated a great deal of research. Perosis is an anatomical deformity of the leg bones of young chickens, turkeys, pheasants, grouse and quail. It is distinct from rickets inasmuch as calcification of the bones involved is normal.

Symptoms of Perosis: Perosis is characterized by a gross enlargement of the hock or tibial-metatarsal joint, a twisting or bending of the distal end of the tibia and of the proximal end of the metarsus, and slipping of the gastrocnemius tendon from its condyles. The latter symptom causes complete crippling in the affected leg. If both legs are so affected, death usually follows.

Investigators studying this disease had noticed that feeds containing large excesses of calcium and phosphorus frequently aggravated the condition. It was with some surprise, therefore, that a group of research workers at Cornell University (22) noted a curative or preventive effect while administering a series of calcium-phosphorus compounds designed to induce perosis. These workers, Wilgus, Norris and Heuser, had been incorporating in the chick feeds a number of such compounds, including chemically pure monocalcium phosphate, dicalcium phosphate and tricalcium phosphate, and had found that all increased the severity of the perosis. The use of a technical grade of monocalcium phosphate, however, prevented the disease.

This unexpected effect could be attributed only to an impurity in the technical grade preparation. This material was therefore fractionated in order to seek out the impurity possessing anti-perotic properties. At the same time, a spectrographic analysis of the original material was made, revealing manganese and iron as the two main impurities. The same impurities were found in the active fraction, while the inactive fraction contained only calcium, sodium and aluminum.

Furthermore a careful analysis of wheat germ, known to be an effective anti-perotic material, revealed large traces of manganese as well as lesser amounts of magnesium, zinc, sodium, potassium, calcium and phosphorus. A final analytical study was made in which the ash of the hocks of normal and afflicted birds was compared. Manganese was found in the normal bone ash, but was entirely absent from the abnormal bone ash.

On the basis of this circumstantial evidence, manganese was added directly as a supplement to the basal diet in order to observe its effect

on the development of perosis. (Because of their coincidental occurrence, the effects of iron, aluminum and zinc were also tested). *In all cases, the addition of manganese prevented nearly all the symptoms of perosis.* Aluminum and zinc had very slight beneficial effects, while iron was quite ineffective.

Following this experiment, a number of feedstuffs were analyzed for manganese content. It was found that those feedstuffs which are known to be most effective in the prevention of perosis are usually rich in manganese.

The necessity of manganese for the prevention of perosis has since been confirmed by a great many investigators in poultry nutrition (23, 24, 25, 26, 27, 28).

Manganese Requirement of Chicks: The minimum perosis preventive amount of manganese depends upon several factors of which the manganese content in the ration of the mother hen and the calcium and phosphorus content of the chick's diet appear to be the most important. An intake of 35 to 40 p.p.m. manganese is suggested by Insko *et al* (27). This requirement has been shown to vary with the breed of chicks, certain New Hampshire chicks being more susceptible to the disease and therefore requiring more manganese than, for example, White Leghorns (23). Fairly large supplements of manganese have been given without evidence of toxicity (646 to 1000 p.p.m. manganese).

Continued studies on perosis in poultry have revealed the fact that other dietary factors, in addition to manganese, play an important part in the prevention of this disease. It is now generally accepted that a so-called "anti-perosis complex" exists, embodying at least four nutritional factors. These include manganese, choline, biotin* and an unknown organic nutrient found in an aqueous liver extract (29).

Other Functions of Manganese in Poultry: In addition to its importance in the prevention of perosis, manganese has been found essential for the normal bone development of the embryonic chick (30, 31). Hens fed a perosis-producing diet lay eggs of low hatchability, with a high proportion of embryos having short thickened legs and wings and globular heads. This condition is known as *chondrodystrophy.* Its relation to manganese starvation has been pointed out by Lyons and Insko (32) who showed that the deformed embryos

* A discussion of the role of biotin in perosis has been given in *Borden's Review of Nutrition Research,* March 1943.

contained less manganese than the normal ones and further, that normal embryonic development could be secured by feeding manganese to the mother hen. They found also that injection of manganese (0.03 mg.) directly into the eggs is equally effective as feeding manganese to the mother hen.

Manganese in Human Nutrition

Requirement: As yet, manganese has not been demonstrated to be indispensable in the human diet. It occurs in all human tissues. Human blood contains about 2 micrograms of manganese per 100 cc., about twice as much occurring in the plasma as in the cells. The liver contains the largest amount of manganese, 170 micrograms per 100 grams of fresh tissue; kidney tissue contains about 61 micrograms; lung tissue about 20 micrograms and nervous tissue still less (33).

In vitro studies indicate that a number of important enzyme systems are activated by manganese (17). Phosphatases (bone, liver, yeast, kidney), arginase, cozymase, carboxylase, and cholinesterase are a few examples of enzymes upon which manganous ions exert a potentiating effect. Some presumptive evidence exists to indicate that the activation of enzymes by manganese occurs in the body as well. This phase of manganese activity is now undergoing investigation.

On the basis of animal studies, and on the basis of the intimate chemical relationship existing between manganese and a number of important enzyme systems, and in view of the significant occurrence of manganese in human tissues, it seems quite likely that this element is an important factor in human nutrition, although further studies are necessary to determine the exact nature of its function.

It has been suggested by Everson and Daniels (34) that manganese is essential to the physiological development of children, on the basis of dietary balance studies with preschool age children. These investigators conducted a series of twelve manganese balance studies on seven children, at three different levels of ingestion. They found that the amount of manganese retained is proportionate to the amount ingested, indicating that the element apparently is utilized in the normal metabolism of young children. From an analysis of the results of these balance studies, they suggest that the diet of pre-school age children should contain from 0.02 to 0.03 mg. of manganese per kilogram (2.2 lbs.) of body weight.

Following the recognition of the importance of copper as a complement to iron in the formation of hemoglobin, speculation arose as

to whether other elements could replace copper in this vital function. Titus *et al* (35), as well as others, have suggested that manganese may play an important part in hemoglobin formation, but this has been refuted by a number of investigators (36). Manganese, it is now generally believed, plays no part in hemoglobin production, but on a milk- copper- iron diet, the addition of manganese improves the rate of growth and permits reproduction in experimental animals (37).

Sources: The average daily adult diet has been found to contain about 4 mg. of manganese (38), substantially the same amount being excreted. It has been estimated that this intake varies from about 0.80 mg. per day for 3 or 4 year old children to as high as 8.4 mg. for the working man (39).

The manganese content of a wide variety of foods has been determined (39, 40, 41). In general, cereals and plant foods are highest, with meat, poultry, dairy products and fish following in the order listed. Wheat bran and blueberries have been found to be exceptionally high in manganese.

Several interesting reviews have appeared on the subject of the nutritional and physiological importance of manganese (42, 43, 17, 44, 45, 46).

Conclusion

Manganese has been regarded as one of the biologically essential trace elements since the end of the nineteenth century. Early studies revealed the indispensability of this element to proper plant growth and manganese is now used routinely as an ingredient in plant nutrient solutions and in many soil fertilizers.

More recently, the importance of manganese in proper growth and in normal reproductive functioning of experimental animals has been demonstrated. Its practical significance in the prevention of perosis in poultry has been established and it is also recognized as being essential to egg hatchability and to normal bone development in chicks.

The significance of manganese in human nutrition is suggested by animal studies and by limited human studies. The intimate chemical relationship between manganese and a number of important enzyme systems, as well as its common occurrence in foods and in animal tissues, offers further indications of the probable importance of manganese in human nutrition. More conclusive evidence of the human need for manganese rests with future research.

REFERENCES CITED

1. BERTRAND, G. Bull. Soc. chim., Paris *17*, 3rd Ser. 753 (1897).

2. BERTRAND, G. and F. MEDIGRECEANU. Ann. Inst. Pasteur. *27*, 1, 282 (1913).

3. REIMAN, C. K. and A. S. MINOT. A method for manganese quantitation in biological material together with data on the manganese content of human blood and tissues. J. Biol. Chem. *42*, 329 (1920).

4. MCHARGUE, J. S. The role of manganese in plants. J. Am. Chem. Soc. *44*, 1592 (1922).

5. SKINNER, J. T., W. H. PETERSON and H. STEENBOCK. The manganese metabolism of the rat. J. Biol. Chem. *90*, 65 (1931).

6. LEVINE, V. E. and H. A. SOHM. The effect of manganese in growth. J. Biol. Chem. *59*, xlviii Proc. (1924).

7. RICHET, C., GARDNER and GOODBODY. Compt. rend. Acad. *181*, 1105 (1925).

8. MCHARGUE, J. S. Further evidence that small quantities of copper, manganese and zinc are factors in the metabolism of animals. Am. J. Physiol. *77*, 245 (1926).

9. BERTRAND, G. and H. NAKAMURA. Compt. rend. Acad. *186*, 1480 (1928).

10. MCCARRISON, R. Effect of manganese on growth. Ind. J. Med. Res. *14*, 641 (1927).

11. ORENT, E. R. and E. V. MCCOLLUM. Effects of deprivation of manganese in the rat. J. Biol. Chem. *92*, 651 (1931).

12. KEMMERER, A. R., C. A. ELVEHJEM and E. B. HART. Studies on the relation of manganese to the nutrition of the mouse. J. Biol. Chem. *92*, 623 (1931).

13. WADDELL, J., H. STEENBOCK, E. B. HART and E. VAN DONK. Growth and reproduction on milk diets. J. Nutr. *4*, 53 (1931).

14. SKINNER, J. T., E. VAN DONK and H. STEENBOCK. Manganese as a factor in reproduction. Am. J. Physiol. *101*, 591 (1932).

15. KEIL, H. L., H. H. KEIL and V. E. NELSON. The effect of addition of minerals and sucrose to milk as shown by growth, fertility and lactation of the rat. Am. J. Physiol. *108*, 215 (1934).

16. DANIELS, A. L. and G. J. EVERSON. The relation of manganese to congenital debility. J. Nutr. *9*, 191 (1935).

17. SHILS, M. E. and E. V. MCCOLLUM. The trace elements in nutrition. J. Am. Med. Assoc. *120*, 609 (1942).

18. PERLA, D. and M. SANDBERG. Metabolic interdependence of vitamin B_1 and manganese: Reciprocal neutralization of their toxic effects. Proc. Soc. Exp. Biol. Med. *41*, 522 (1939).

19. SANDBERG, M., D. PERLA and O. M. HOLLY. Interdependence of vitamin B_1 and manganese. II. Mn, Cu, Fe metabolism in vitamin B_1 deficient rats. Proc. Soc. Exp. Biol. Med. *42*, 368 (1939).

20. PERLA, D., M. SANDBERG and O. M. HOLLY. Interdependence of vitamin B_1 and manganese. III. Mn, Cu, Fe metabolism in normal rats. Proc. Soc. Exp. Biol. Med. *42*, 371 (1939).

21. WILLIAMS, R. R. and T. D. SPIES. *Vitamin B_1 and Its Use in Medicine*. p. 286. Macmillan, N. Y. (1938).

22. WILGUS, H. S. JR., L. C. NORRIS and G. F. HEUSER. The role of manganese and certain other trace elements in the prevention of perosis. Jr. Nutr. *14*, 155 (1937).

23. GALLUP, W. D. and L. C. NORRIS. The amount of manganese required to prevent perosis in the chick. Poultry Sci. *18*, 76 (1939).

24. HELLER, V. G. and R. PENQUITE. Factors producing and preventing perosis in chickens. Poultry Sci. *16,* 243 (1937).

25. SCHAIBLE, P. J., S. L. BANDEMER and J. A. DAVIDSON. Poultry Sci. *16,* 367 Proc. (1937).

26. LYONS, M., W. M. INSKO, JR., and J. H. MARTIN. The effect of intraperitoneal injections of manganese, zinc, aluminum and iron salts on the occurrence of slipped tendon in chicks. Poultry Sci. *17,* 12 (1937).

27. INSKO, W. M., JR., M. LYONS and J. H. MARTIN. The quantitative requirement of the growing chick for manganese. J. Nutr. *15,* 621 (1938).

28. WIESE, A. C., C. A. ELVEHJEM, E. B. HART and J. G. HALPIN. Studies on the prevention of perosis in the chick. Poultry Sci. *17,* 33 (1938).

29. RICHARDSON, L. R., A. G. HOGAN and O. N. MILLER. The relation of biotin to perosis in chicks. Univ. Missouri Coll. Agr. Research Bull. 343, June (1942).

30. GALLUP, W. D. and L. C. NORRIS. Essentialness of manganese for normal development of bone. Science *87,* (1938).

31. CASKEY, C. D., and W. D. GALLUP and L. C. NORRIS. The need for manganese in the bone development of the chick. J. Nutr. *17,* 407 (1939).

32. LYONS, M. and W. M. INSKO, JR. Kentucky Agr. Exp. Sta. Bull. No. 371, 63 (1937).

33. SHOHL, A. T. *Mineral Metabolism.* Reinhold Publishing Co., N. Y. (1939).

34. EVERSON, G. and A. L. DANIELS. A study of manganese retentions in children. J. Nutr. *8,* 497 (1934).

35. TITUS, R. W., H. W. CAVE and J. S. HUGHES. Manganese-copper-iron complex as a factor in hemoglobin building. J. Biol. Chem. *80,* 565 (1928).

36. ELVEHJEM, C. A. Biological significance of copper and its relation to iron metabolism. Physiol. Rev. *15,* 175 (1935).

37. UNDERHILL, F. A., J. M. ORTEN and R. C. LEWIS. The inability of metals other than copper to supplement iron in curing the nutritional anemia of rats. J. Biol. Chem. *91,* 13 (1931).

38. KEHOE, R. A., J. CHOLAK and R. V. STORY. Manganese, lead, tin, aluminum, copper and silver in normal biological material. J. Nutr. *20,* 85 (1940).

39. HODGES, M. A. and W. H. PETERSON. Manganese, copper and iron content of serving portions of common foods. J. Amer. Diet. Assoc. *7,* 6 (1931).

40. PETERSON, W. H. and J. T. SKINNER. Distribution of manganese in foods. J. Nutr. *4,* 419 (1931).

41. REMINGTON, R. E. and H. E. SHIVER. Iron, copper and manganese content of some common vegetables. J. Assoc. Off. Agr. Chem. *13,* 129 (1930).

42. RICHARDS, M. B. Manganese in relation to nutrition. Biochem. J. *24,* 1572 (1930).

43. ROSE, M. S. The nutritional significance of some mineral elements occurring as traces in the animal body. Yale J. Biol. Med. *4,* 499 (1932).

44. VON OETTINGEN, W. F. Manganese: its distribution, pharmacology and health hazards. Physiol. Rev. *15,* 175 (1935).

45. UNDERWOOD, E. J. The significance of the trace elements in nutrition. Nutr. Abst. and Rev. *9,* 515 (1940).

46. BAUDISCH, O. The importance of trace elements in biologic activity. J. Am. Med. Assoc. *123,* 959 (1943).

NEWS DIGEST

B VITAMINS IN GERMINATING SEEDS—Recent experiments show that substantial increases in B vitamins occur in seeds which have been allowed to germinate. Although the thiamin content of germinating seeds is known to increase, the new experiments indicate that such increases also occur in the case of the other members of the vitamin B complex. Tests with germinating black-eyed peas, lima beans and corn showed appreciable increases in the amounts of nicotinic acid, pyridoxin, pantothenic acid, riboflavin, inositol and biotin, in approximately the order named. Thiamin is a borderline case, increasing in germinating peas, but decreasing in lima beans. Folic acid decreases during the germination of peas, but has been found to increase markedly in cottonseed. *Proc. Soc. Exp. Biol. Med. 54,* 53 (1943).

CALCIUM AND LONGEVITY—Research nutritionists have found that experimental animals receiving calcium in amounts greater than adequate for normal growth and reproduction enjoy a greater length of life. In addition, a higher level of adult vitality is reached and the "prime of life" is considerably extended. This increase in longevity is more pronounced in the male than in the female. More recently, however, experiments have shown that unmated females, who do not have to invest the extra calcium in the bearing and suckling of the young, gain in longevity in equal proportion to the gains made by males when given extra calcium. Mated females who receive the calcium supplements; expend the extra supply in rearing more, as well as superior, young. When given still greater amounts of calcium, mated females also were enabled to attain an increased life span. *J. Nutr. 26,* 323 (1943).

AVERAGE AMERICAN DIET—The enrichment of bread and flour with riboflavin and niacin to meet new government standards has effectively increased the dietary intake of these B vitamins, according to a recently reported appraisal of the average American diet. Prior to the enrichment of bread and flour, the average diet, such as was consumed by the middle two-thirds or three-fourths of the American population, contained an estimated 1.4 mg. riboflavin, 11 mg. niacin, and 4.9 mg. pantothenic acid per 2500 calories. These values are appreciably lower than the generally accepted daily requirements. (Riboflavin requirements for adults range from 1.8 mg. to 3.3 mg. per day, depending upon activity and sex; niacin requirements range from 12 mg. to 23 mg. per day; the requirements for pantothenic acid are not yet known, but are estimated to be about 9 to 11 mg. per day.) Enrichment of bread and flour has increased the dietary intake of riboflavin by 12%, to 1.6 mg. per day; of niacin, by 53%, to 17 mg. per day.

Principal contributors of the respective vitamins to ordinary diets are listed as follows, in order of importance: *riboflavin*—milk, white bread, eggs, potatoes and liver; *niacin*—beef, lean pork, fish, white bread and potatoes; *pantothenic acid*—white bread, milk, eggs and potatoes. *J. Nutr. 26,* 417 (1943).

VITAMIN A IN EGGS—Successful reduction of vitamin A loss during the storage of spray-dried eggs has been achieved experimentally by the use of

one or more of three procedures: (1) compression of the egg powder into solid blocks; (2) incorporation of antioxidants such as the tocopherols (vitamin E) in the egg mixture; (3) packing the product in nitrogen or in vacuum. Vitamin A, as well as thiamin, riboflavin, pantothenic acid, and niacin, are all well retained during the process of spray-drying. The chief loss of vitamin A is during subsequent storage. According to latest reports, best results to date in preventing this loss have been obtained by combining two of the above described procedures – compression of dried eggs containing added tocopherols. No loss of vitamin A occurred after six weeks of storage at a temperature as high as 98.6°F. *Amer. Chem. Soc. Convention, Pittsburgh, Sept. 1943.*

THIAMIN AND LEARNING – Increasing the thiamin content of the diet may heighten learning ability to an appreciable extent, according to a recent experiment with school children. A group of 104 children ranging in age from four to twenty years, living under essentially identical conditions in an orphanage, and following the same regimen, acted as subjects. The children were matched in pairs for purposes of control observation, and were then divided into two groups whose members were judged similar in ability to learn, in education, age, sex, size and ratio of weight to expected weight. Diet, motivation, environment and other factors were kept as nearly identical as possible. The only variant was a 2 mg. supplement of thiamin administered to one group. (Conditions were so arranged that neither experimenters nor children knew which group was receiving the vitamin and which a dummy pill.) In every one of a series of eighteen learning tasks, it was found that the vitamin-fed group surpassed the control group in making gains. The gains in learning were judged statistically significant and varied, for different activities, from 7 to 87%. The various gains combined indicate, according to the experimenters, that in general, in the existing situation, the group with the added thiamin improved more than the control group by about 27 per cent. *Effect of Thiamin on Learning, R. F. Harrell, Teachers College. N. Y. 1943.*

IODINATED CASEIN AND MILK PRODUCTION—Feeding iodinated casein to dairy cows increases milk production and butterfat content of the milk, according to experiments conducted recently at a State Agricultural Experiment Station. The administration of thyroxin stimulates milk secretion, but since this hormone is expensive, a synthetic thyroprotein—iodinated casein—was substituted. Administration of the iodinated casein resulted in increases in milk production ranging from 5 to 20%. Total fat production was increased from 25 to 50%. The relatively greater increase in fat production over milk production was due to an increase in the fat test from approximately 3.8 to 5.0%. Since the administration of iodinated casein also caused a slight decrease in body weight and a 33% reduction in the ascorbic acid level of the milk, further studies are essential before this experimental procedure can be considered for adoption in commercial dairy practice. *Amer. Chem. Soc. Convention, Pittsburgh, Sept. 1943.*